Ballast water – the key vector for aquatic species invasions?

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- Regional overviews on introduced species with relative vector importance
- Invasion rates
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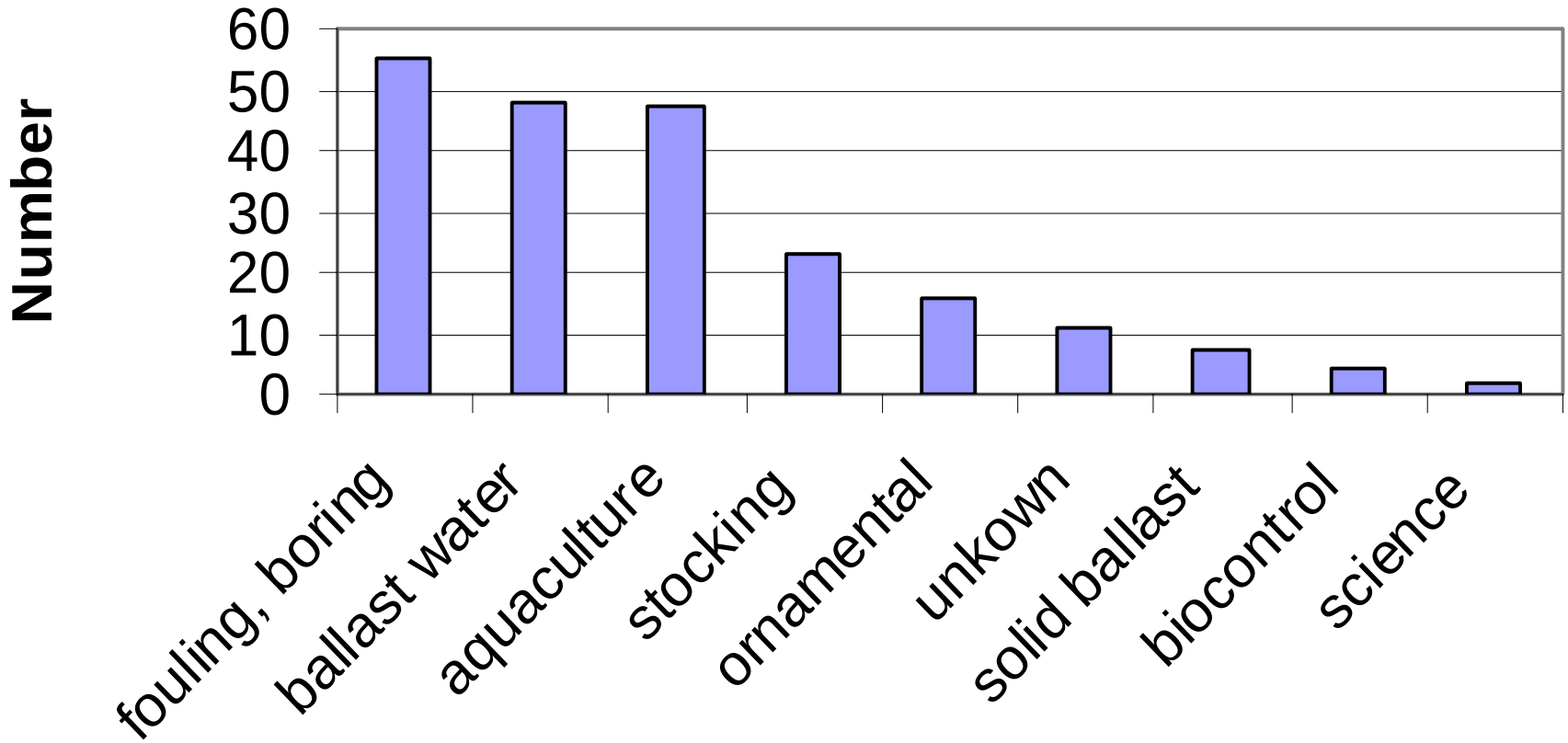
Fact Sheet Shipping

- > 40,000 merchant vessels registered
- Discharge of > 3 billion to ballast water
- > 4,000 species in transit at any time
- > 1,000 taxa sampled from ballast tanks ranging from unicellular algae to fish
- Organism density median in ballast water:
  - phytoplankton 13,300 cells / l
  - zooplankton 400 ind./m^3

Regions Considered

San Francisco Bay - USA



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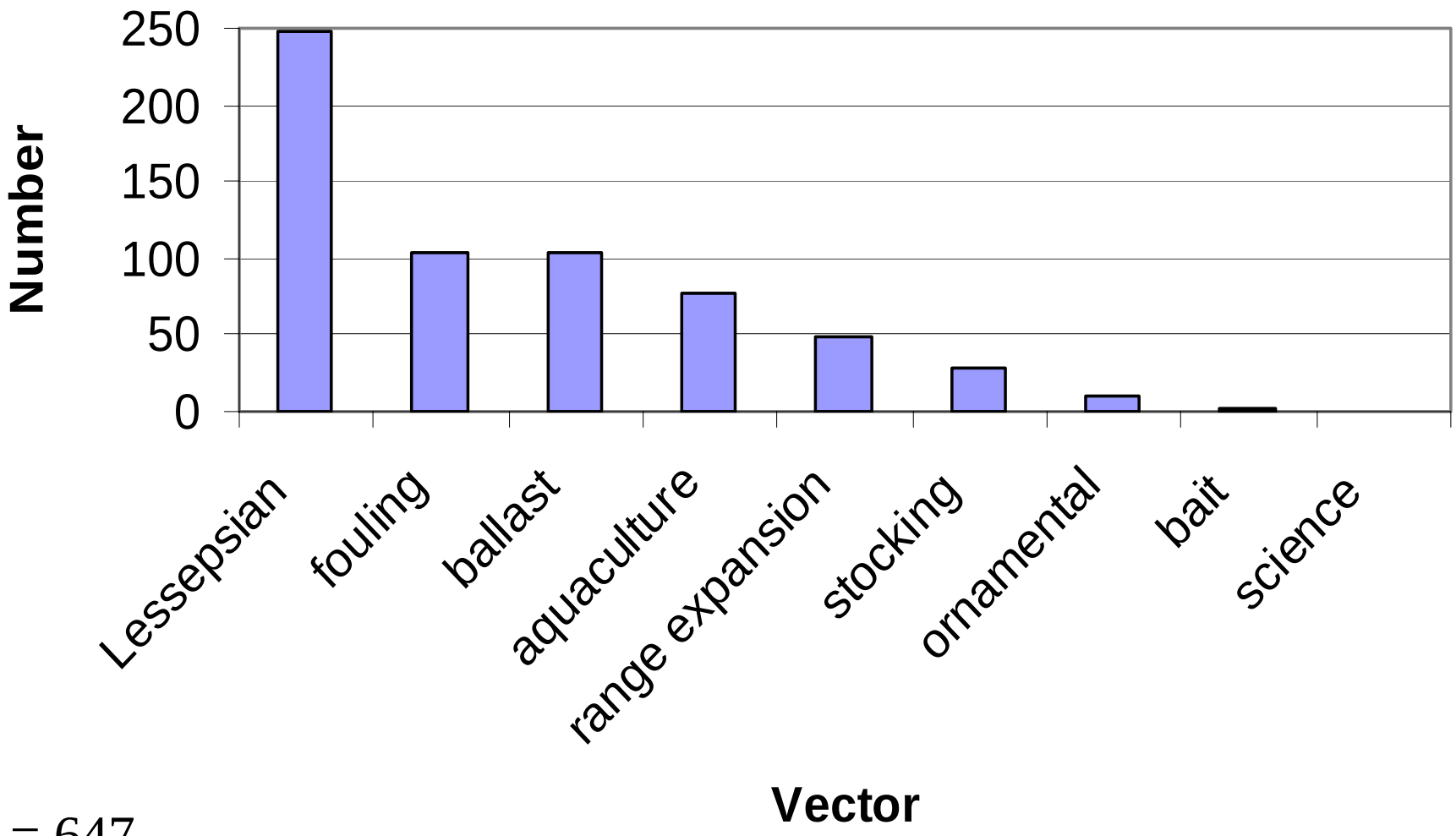
after Cohen & Carlton 1995

Mediterranean Sea



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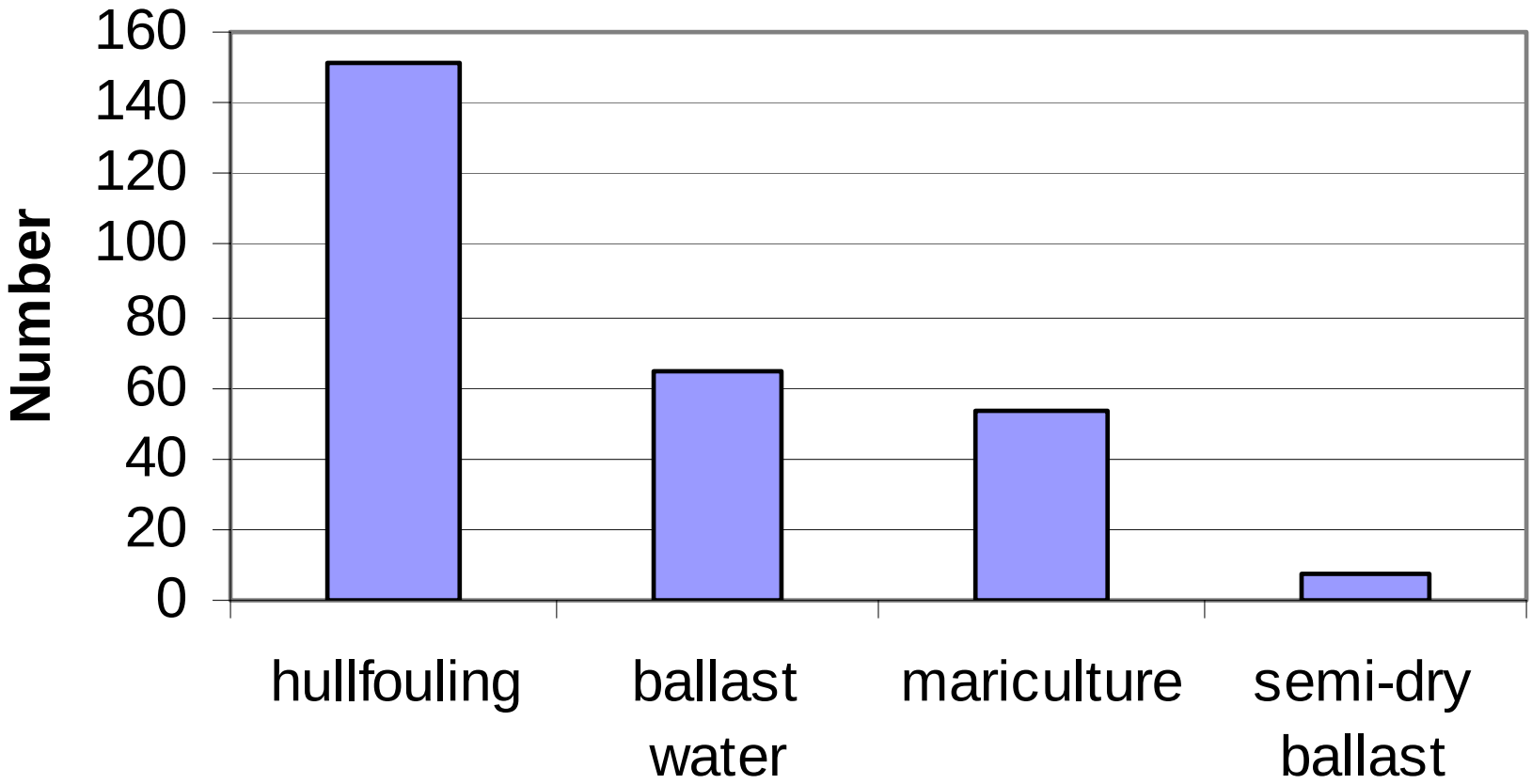
Port Philippe Bay - Australia



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after Hewitt, Campbell, Thresher & Martin 1999

Relative Vector Importance

Vector	Hawaii	PPB	SFB	S-Afr	Braz	Med	Ire	NS	BS	Bl	Ar	EU-At
fouling	80,0	54,9	27,2	47,1	19,5	27,6	21,5	21,8	16,5	16,9	31,4	26,7
ballast		23,3	23,8	41,2	29,9	27,4	19	30,9	37,4	31,3	11,4	25,6
aquaculture		19,3	23,3	11,8	46,8	20,4	31,6	21,2		25,3	34,3	34,4
solid ballast		2,5	3,5									
stocking			11,4			7,7	13,9	13,6	37,4	15,7	11,4	6,7
range exp.						13,0	6,3	5,8	2,9	1,2	11,4	3,1
ornamental			7,9		3,9	2,7	6,3	4,2	5,8	8,4		2,6
biocontrol			2									
science			1			0,3	1,3	1,8				1
bait						0,8		0,6		1,2		

Data for Hawaii cover marine introduced invertebrates (The Nature Conservancy, Defenders of Wildlife & Center for International Environmental Law for COP-7, Kuala Lumpur, Feb. 2004)

Vector Importance

- Fouling, aquaculture and ballast water are the most important vectors in the regions considered
- Mean values of vector importance across all regions result in hull fouling being the most important vector

Vector	Mean all
fouling	32,6
ballast	27,4
aquaculture	26,8
stocking	14,7
range exp.	6,2
ornamental	5,2
solid ballast	3,0
biocontrol	2,0
science	1,1
bait	0,9

Regional Comparison of Hull Fouling vs. Ballast Water

- In eight regions hull fouling is the dominating vector (Arct, PPB, S-Afr., SFB, Ire, EU-At, Med, Hawaii)
- Invaders in four regions are mostly introduced by ballast water (Braz., NS, BlackS, BS)

Region	fouling	ballast
Hawaii	80,0	n.d.
PPB	54,9	23,3
S-Afr	47,1	41,2
Arct	31,4	11,4
Med	27,6	27,4
SFB	27,2	23,8
EU-At	26,7	25,6
Ire	21,5	19,0
Braz	19,5	29,9
NS	21,8	30,9
BS	16,5	37,4
Bl	16,9	31,3

European Focus

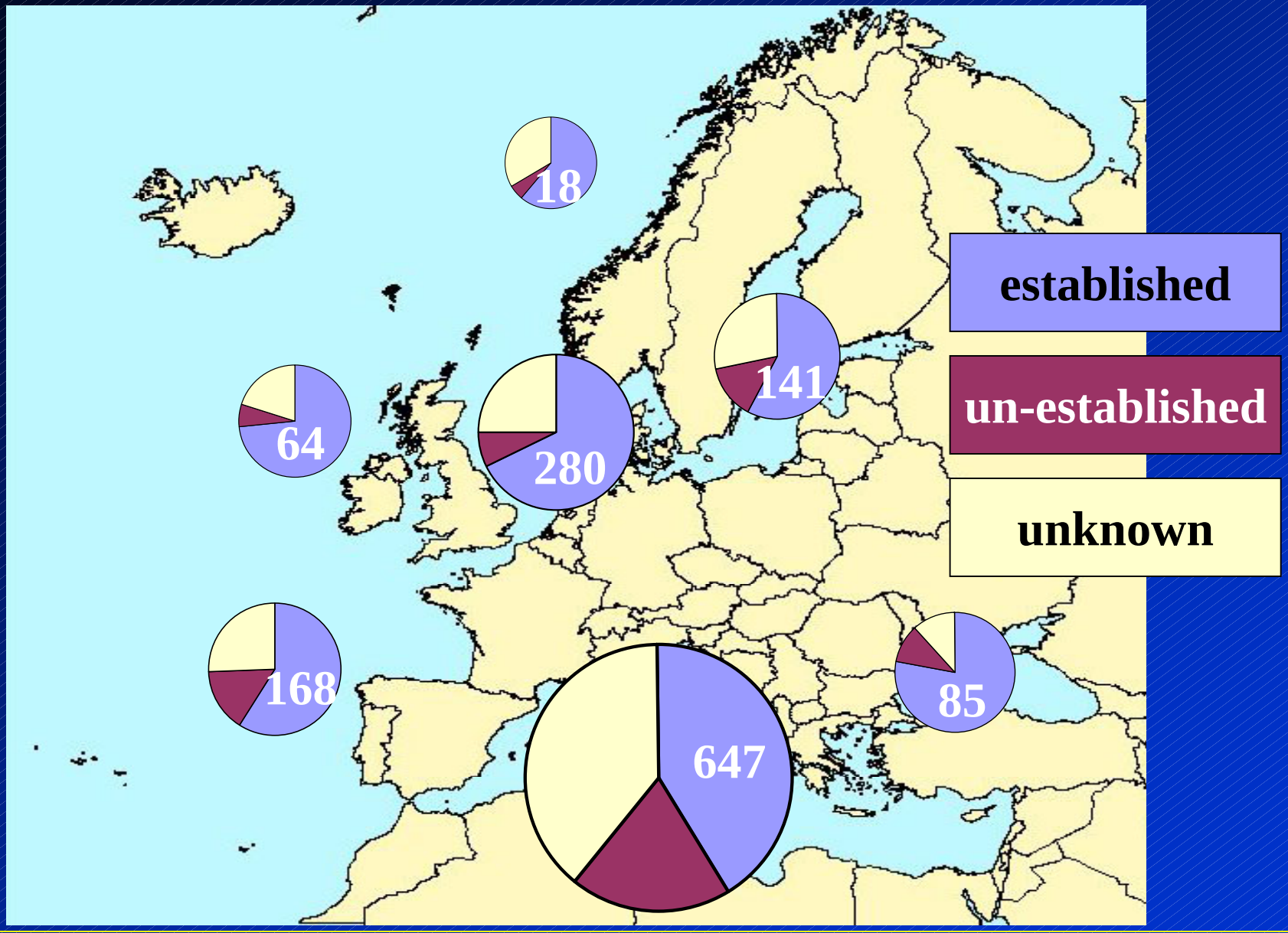
- Seas of all EU Member states plus Norway, non-EU Mediterranean Sea and Black Sea (approx. 80,000 km coastline)
- Adjacent water bodies (lakes, estauries etc.)
- Temperature range from arctic to warm-temparate conditions
- Salinity range from freshwater to marine conditions
- Various habitats including rocky shores, sandy beaches, mud flats

Overview

- 1,036 non-indigenous species are known to occur in the regions considered
- The region with the highest number of invaders is the Mediterranean Sea

Region	Number	%
Mediterranean Sea	647	46,1
North Sea	280	20,0
Atlantic coast	168	12,0
Baltic Sea	141	10,0
Black Sea	85	6,1
Irish Waters	64	4,6
Arctic waters	18	1,3
Total	**1403**	

Invaders per Region



Invaders per Region

- Most invaders occur in one region (so far)
- However, 5 invaders are known from 6 regions:
  - *Ficopomatus enigmaticus*
  - *Eriocheir sinensis*
  - *Elodea canadensis*
  - *Colpomenia peregrina*
  - *Bannemaisonia hamifera*
- Another 5 species were found throughout the entire 7 regions considered:
  - *Teredo navalis, Mya arenaria, Crassostrea gigas, Balanus improvisis* and *Oncorhynchus mykiss*

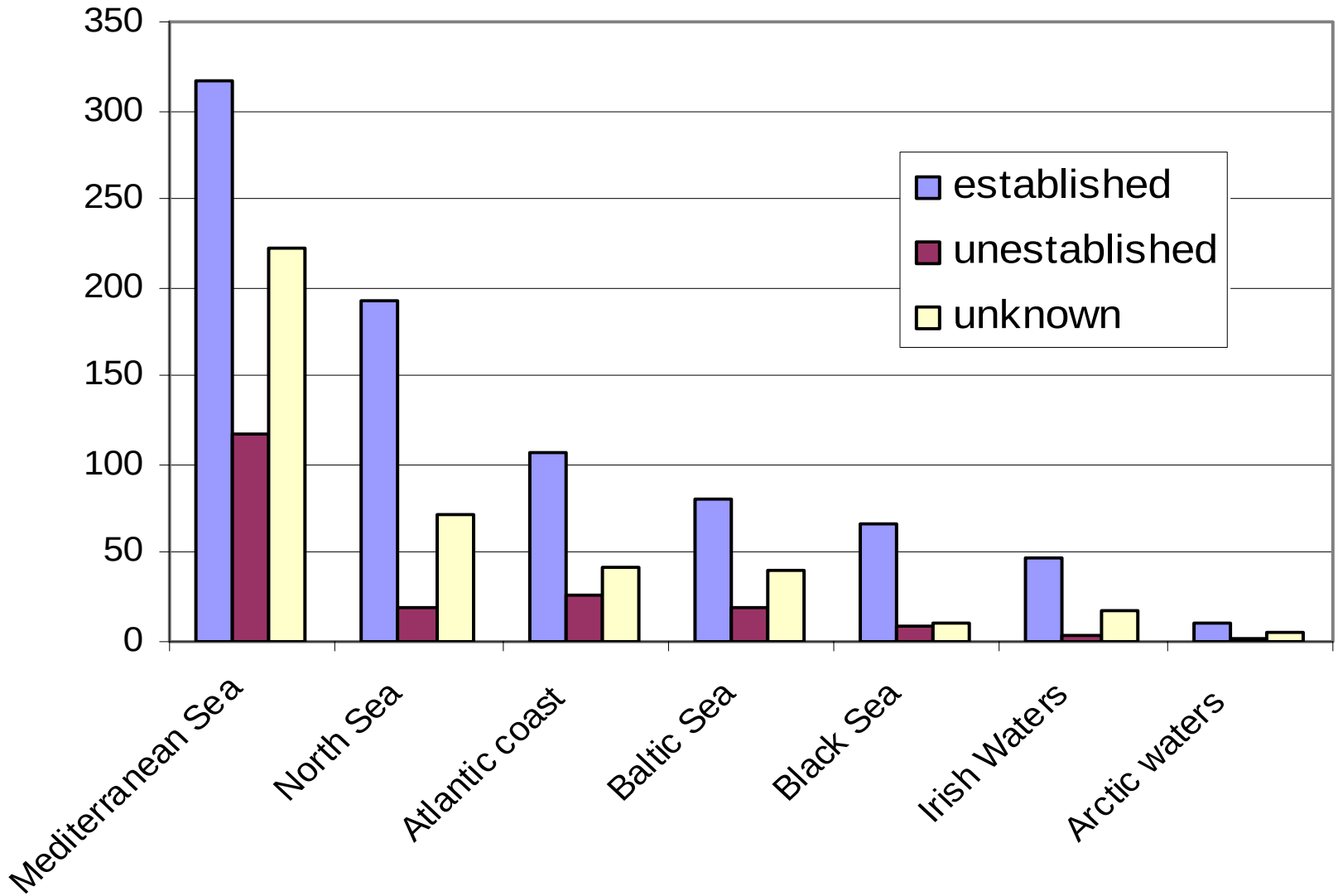
Number of regions invaded	Number of invaders	%
1	816	80,6
2	93	9,2
3	55	5,4
4	24	2,4
5	15	1,5
6	5	0,5
7	5	0,5

Invaders According to Taxonomic Groups

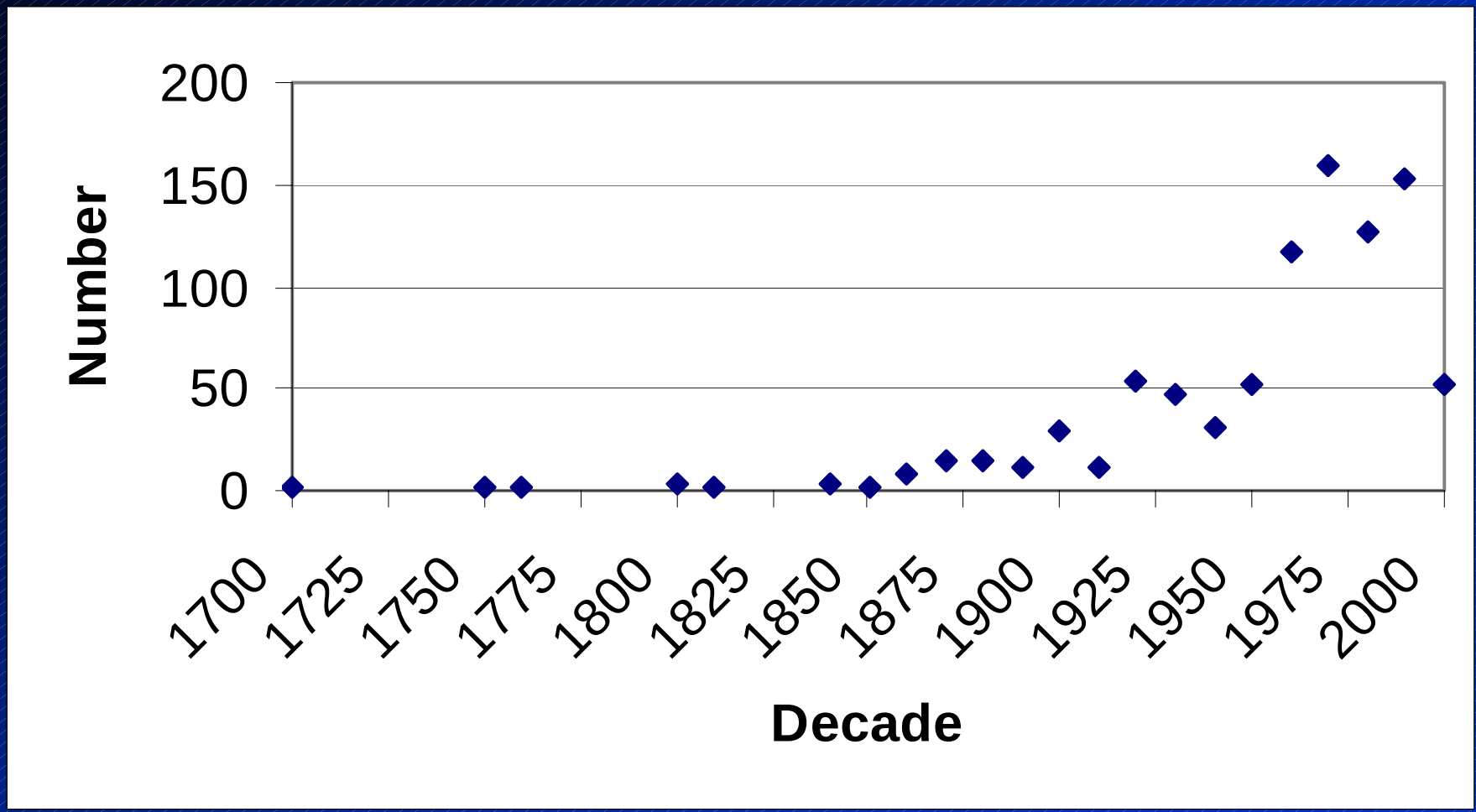
Taxon. Group	Number	%
ZOOBENTHOS	544	53,7
FISH	185	18,3
PHYTOBENTHOS	170	16,8
PHYTOPLANKTON	61	6,0
ZOOPLANKTON	38	3,8
PROTOZOA	15	1,5

- More than half of the invaders known are zoobenthos species
- Is this the best studied group?

Established vs. un-established

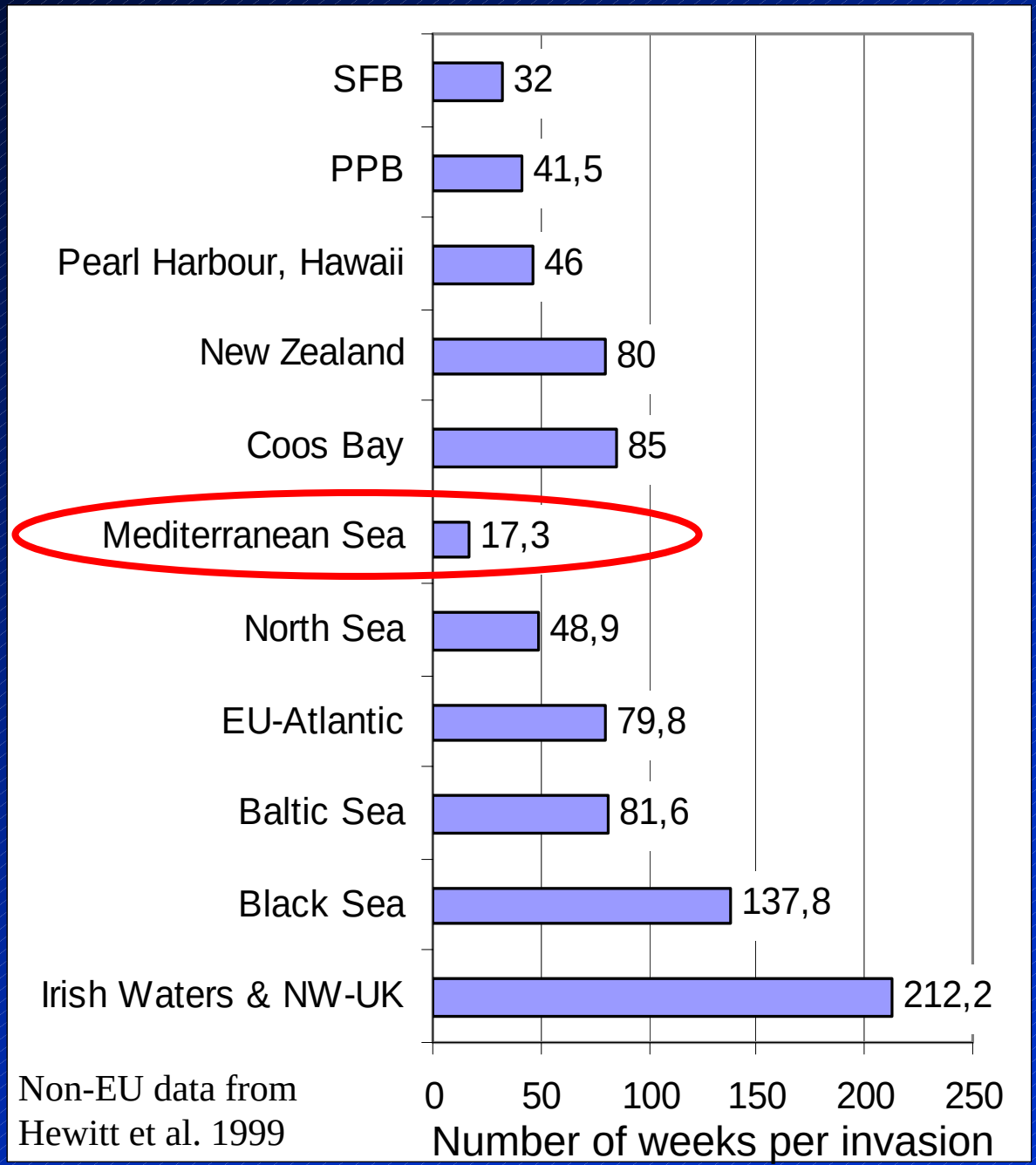


Timeline of invasions all EU regions



Invasion rate

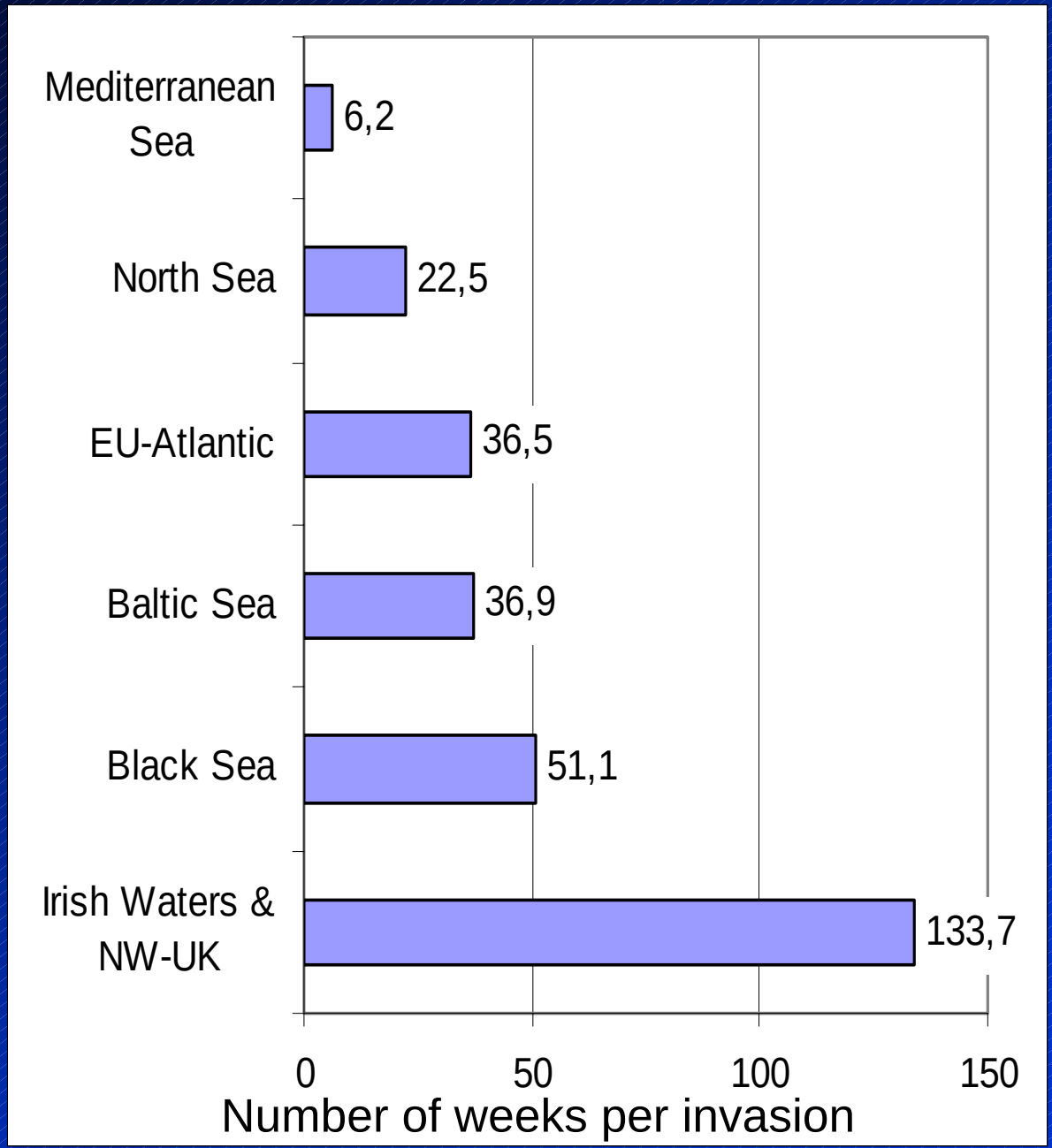
- Data since 1800
- Max: every 4,3 months a new species in Med.
- Min: every 4 years in Irish&NW UK
- Mean: 1,5 years



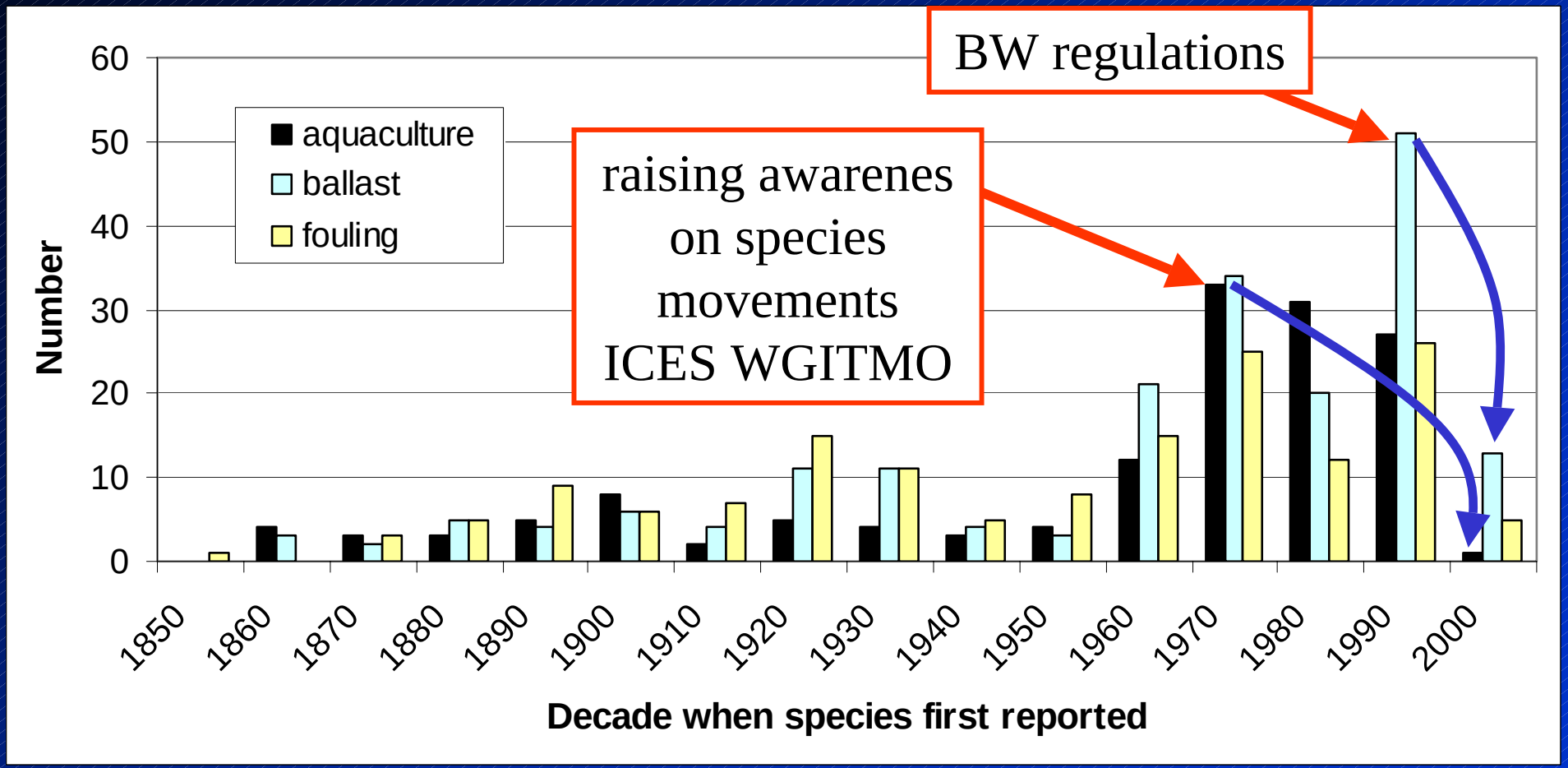
Non-EU data from Hewitt et al. 1999

Invasion rate

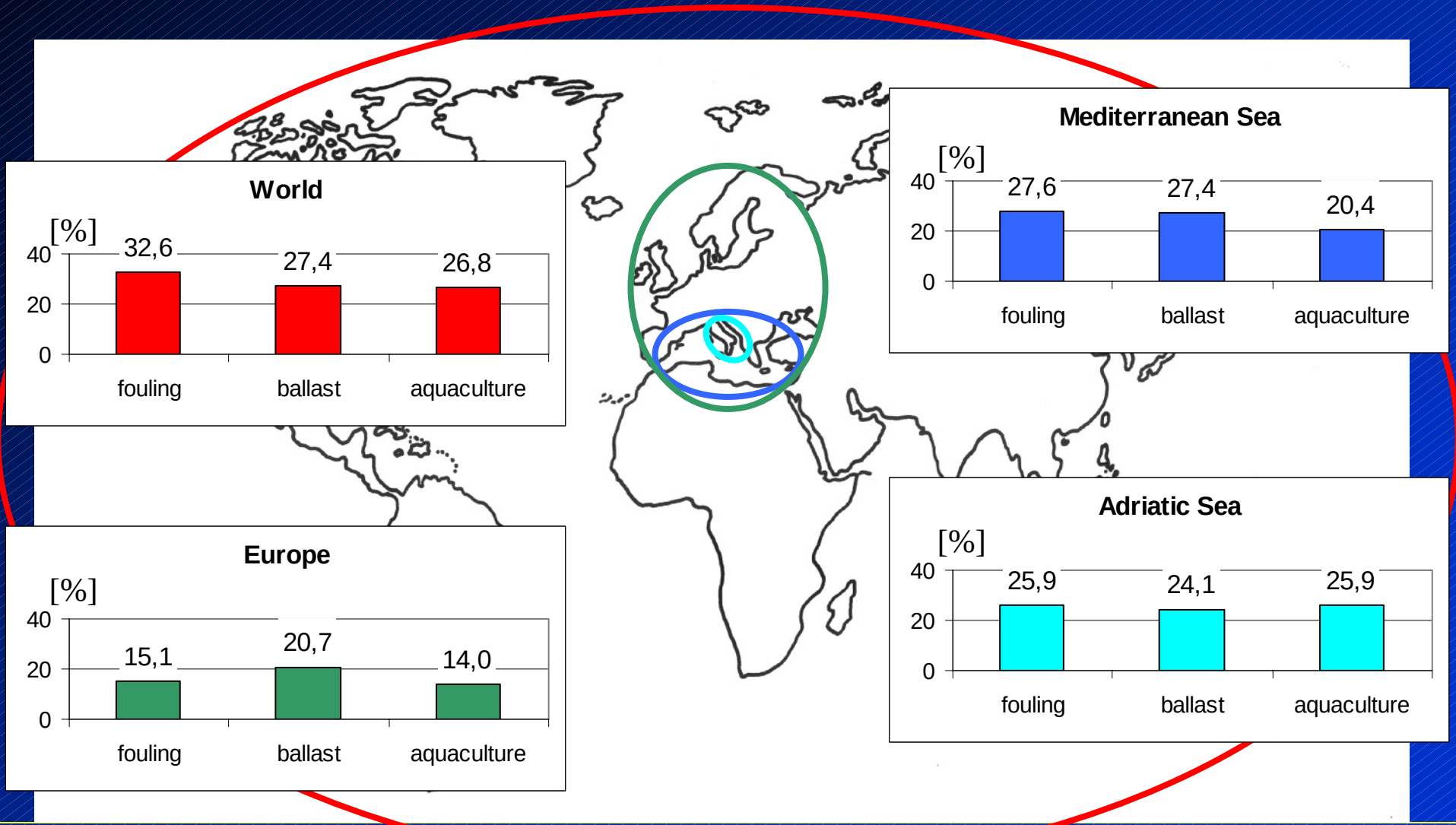
- Data since 1950
- Max: every 6,2 weeks a new species in Med.
- Min: every 2.6 years in Irish&NW UK
- Mean: 0,9 years



Changes in Introduction Vectors EU



Global vs. Regional Approach



International Response - Shipping

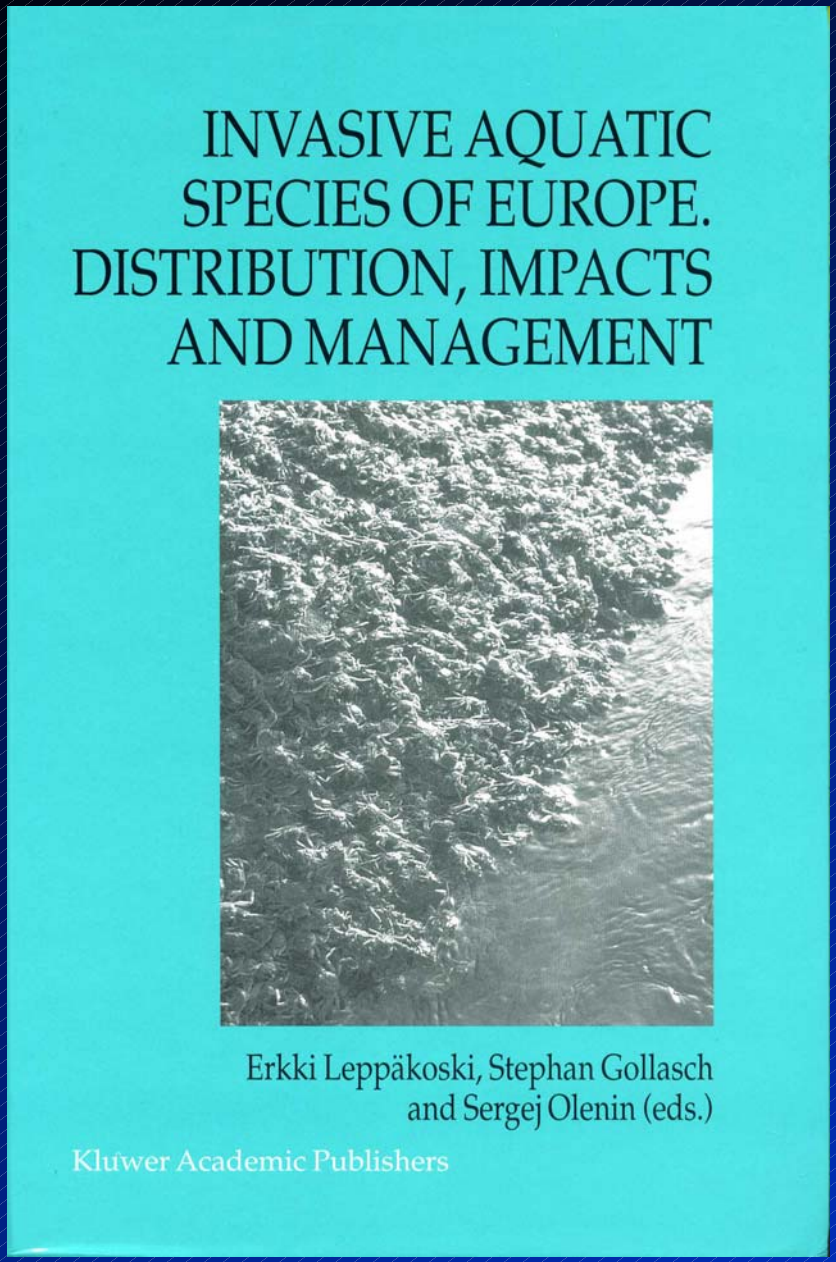
- International Maritime Organization
  - Marine Environment Protection Committee
  - Ballast Water Working Group
    - during 14 years of work two guidelines and the International Ballast Water Management Convention were prepared
    - Convention on Anti-fouling Systems
- Various national regulations on ballast water and hull fouling
- Ballast Water Strategies in development in Europe (EU, HELCOM, OSPAR, ICES)

Summary

- Most important introducing vectors are hull fouling, ballast water and aquaculture
- Vector importance is regionally very different
  - In 8 of 12 regions considered (= 60%) hull fouling is the dominating vector
  - Introductions for aquaculture purposes are the key vector in three regions
- The invasion rate is increasing towards the end of the last century

Outlook

- Ballast water regulations will hopefully reduce the invasion rate
- However, even if the vector ballast water is regulated species invasions will continue as hull fouling is an important and regionally even the dominating vector



Thank you very much for your attention !

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